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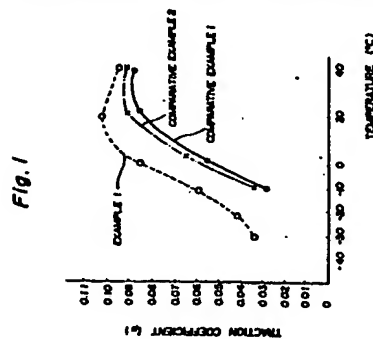
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54 Lubricating oil compositions for traction drive.

- 57 The present invention relates to a lubricating oil composition for traction drive, which consists essentially of:
- (A) a base oil containing as the main component a saturated hydrocarbon or hydrocarbons having fused ring and/or nonfused ring,
  - (B) an ethylene- $\alpha$ -olefin copolymer having a number-average molecular weight of 800 to 8,000, and
  - (C) an anti-wear agent.

The lubricating oil compositions of the present invention are effectively used in winter and cold districts, since they have a high coefficient of traction and show a limited change in the coefficient of traction at low temperatures.



## LUBRICATING OIL COMPOSITIONS FOR TRACTION DRIVE

## BACKGROUND OF THE INVENTION

Field of the Invention

6 The present invention relates to a lubricating oil composition for traction drive and, more particularly, to a lubricating oil composition which has a high coefficient of traction, shows a limited change in the coefficient of traction at low temperatures, excels in wear resistance, load carrying capacity, thermal and oxidation stability and rust preventing property, and can effectively be used as the lubricating oil for power  
10 transmission systems including a traction drive mechanism.

Statement of the Prior Art

15 In recent years, traction drives (friction driving device utilizing rolling contact) have been applied as the continuously variable transmission for automotive and industrial purposes. The fluids used for such traction drives are required to have a high coefficient of traction and excel in power transmission efficiency.

A number of proposals have been made of the traction drive fluids meeting such demands (for instance, Japanese Patent Publication Nos. 46-338, 46-339, 47-35763 and 58-27838). All these proposals have their  
20 objects to improve the coefficient of traction.

As a result of testing the performance of such fluids for traction drive with actual machines, however, it has been found that they are poor in power transmission ability at low temperatures, and are thus practically unsatisfactory. In power transmission systems exposed to low to high temperature environments, the coefficient of traction of these fluids changes depending upon temperature and, in particular, drops  
25 remarkably at low temperatures. Thus, problems arise in connection with practical performance in winter and cold districts.

## SUMMARY OF THE INVENTION

30 In view of the foregoing problems, a main object of the present invention is to provide a lubricating oil composition for traction drive, which has an increased coefficient of traction, shows a limited change in the coefficient of traction at low temperatures, and excels in wear resistance, load carrying capacity, thermal and oxidation stability and rust preventing property.

35 According to the present invention, this object is achieved by the provision of a lubricating oil composition for traction drive, which consists essentially of:

- (A) a base oil containing as the main component a saturated hydrocarbon or hydrocarbons having fused ring and/or nonfused ring,
- (B) an ethylene- $\alpha$ -olefin copolymer having a number-average molecular weight of 800 to 8,000, and  
40 (C) an anti-wear agent.

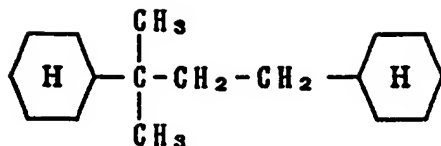
## BRIEF DESCRIPTION OF THE DRAWING

45 Figure 1 shows the coefficients of traction measured in Example 1 and Comparative Examples 1 and 2.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

50 In the present invention, a base oil containing as the main component a saturated hydrocarbon or hydrocarbons having fused ring and/or nonfused ring is used as the component (A). Various saturated hydrocarbons may be used to this end. In particular, it is preferred to use saturated hydrocarbons containing cyclohexyl group and/or decalyl group, and saturated hydrocarbons of 10 to 40 carbon atoms. By way of example, the following saturated hydrocarbons containing cyclohexyl group and/or decalyl group may be used. 3-methyl-1,3-dicyclohexylbutane expressed by:

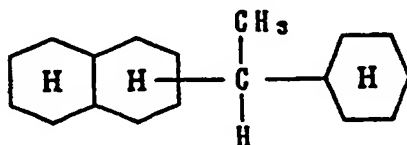
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1-cyclohexyl-1-decalylethane expressed by:

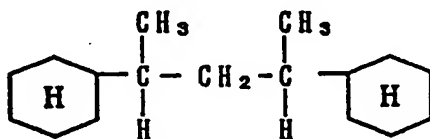
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2,4-dicyclohexylpentane expressed by:

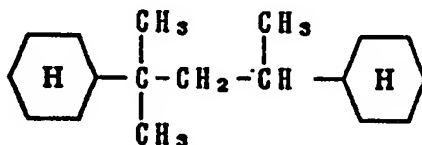
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2-methyl-2,4-dicyclohexylpentane expressed by:

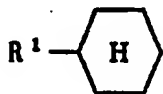
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Alkylcyclohexanes expressed by:

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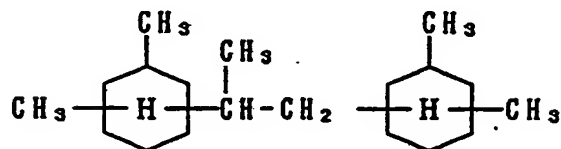
wherein R<sup>1</sup> stands for an alkyl group having 10 to 30 carbon atoms. By way of example, reference may be made to isododecylcyclohexane and isopentadecylcyclohexane.

Besides, the following saturated hydrocarbons having fused ring and/or nonfused ring may be used as the component (A) in the present invention.

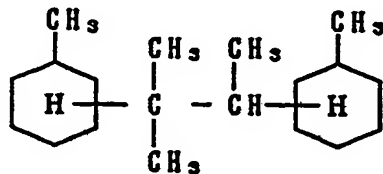
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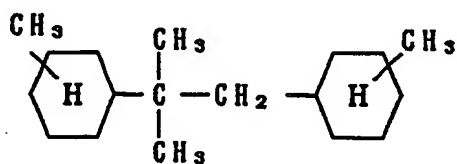
1,2-di(dimethylcyclohexyl)propane expressed by:



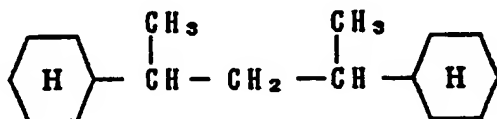
2,3-di(methylcyclohexyl)-2-butane expressed by:



1,2-di (methylcyclohexyl)-2-methylpropane expressed by:



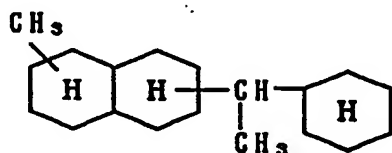
2,4-dicyclohexylpentane expressed by:



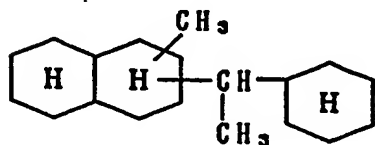
Cyclohexylmethyldecalin expressed by:



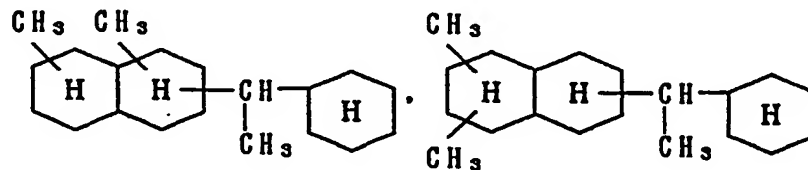
1-(methyldecalyl)-1-cyclohexylethane expressed by:



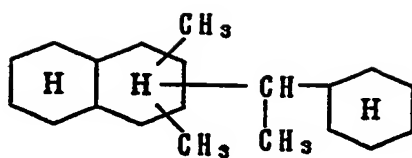
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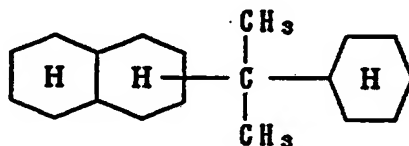
1-(dimethyldecalyl)-1-cyclohexylethane expressed by:



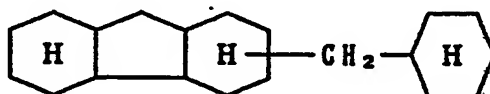
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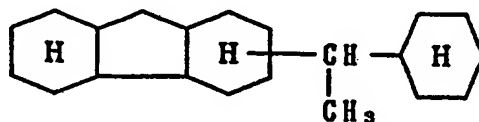
2-decalyl-2-cyclohexylpropane expressed by:



Cyclohexylmethyl perhydrofluorene expressed by:



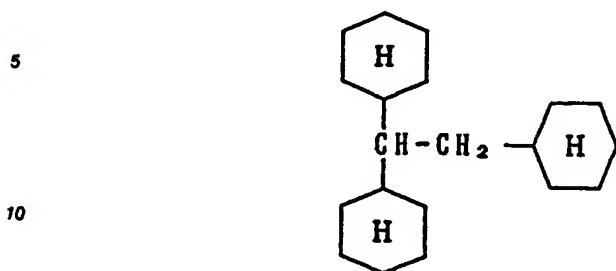
1-perhydrofluorenyl-1-cyclohexylethane expressed by:



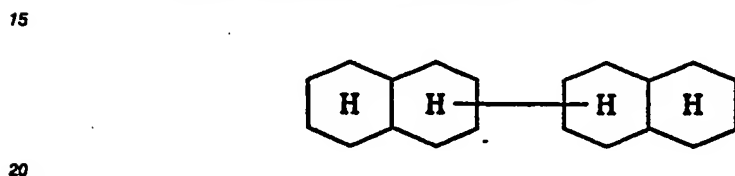
Cyclohexylmethyl perhydroacenaphthene expressed by:



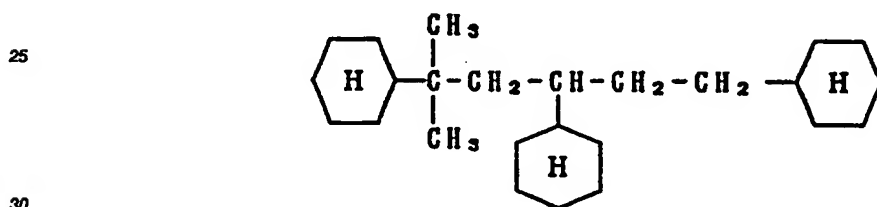
1,1,2-tricyclohexylethane expressed by:



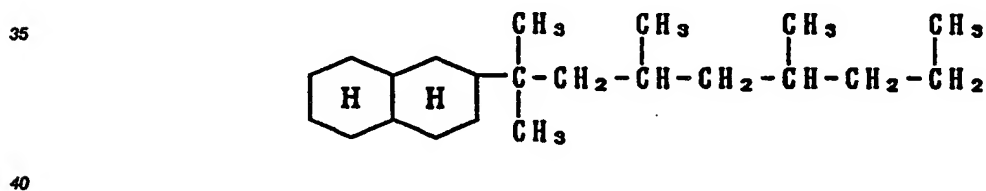
Bis-decalin expressed by:



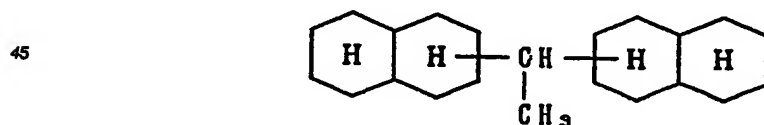
1,3,5-tricyclohexyl-5-methylhexane expressed by:



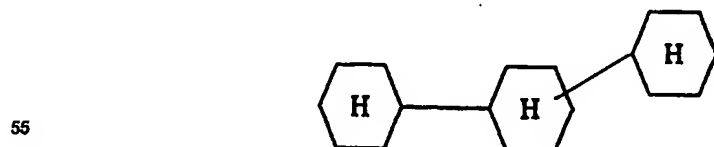
2-(2-decalyl)-2,4,6-trimethylnonane expressed by:



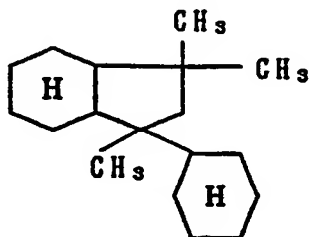
1,1-didecalylethane expressed by:



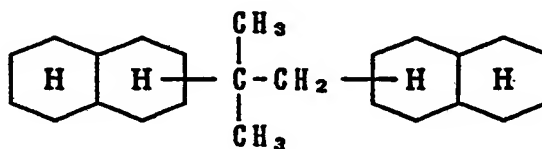
Tercyclohexyl expressed by:



1,1,3-trimethyl-3-cyclohexylhydrindane expressed by:



2-methyl-1,2-didecalylpropane expressed by:



These hydrocarbons may be used alone or in combination of more than 2 kinds.

Among others, preference is given to 1-cyclohexyl-1-decylethane expressed by:



Preferably, this hydrocarbon should contain the cis-type compound in a larger amount, inter alia, in an amount of 50% or higher.

In the present invention, the component (A) is a base oil composed mainly of the aforesaid saturated hydrocarbon or hydrocarbons having fused ring and/or a nonfused ring, which may further contain mineral oils, particularly naphthenic mineral oil and synthetic oils such as polybutene and alkyl benzene in proportions of up to 50%.

In the present invention, the component (B) used is an ethylene- $\alpha$ -olefin copolymer having a number-average molecular weight of 800 to 8,000, preferably 1000 to 5,000, and more preferably 2,000 to 4,000. Copolymers having a number-average molecular weight of below 800 and exceeding 8,000 are unpreferred, since the reduction in the coefficient of traction at low temperatures is increased. The ethylene- $\alpha$ -olefin copolymers should have a kinematic viscosity of 20 to 10,000 cSt, preferably 40 to 8,000 cSt at 100°C. The ethylene- $\alpha$ -olefin copolymers are oligomers of ethylene with  $\alpha$ -olefins having 3 to 20 carbon atoms, for instance, propylene, 1-butene and 1-decene, and are hydrocarbonic synthetic oils free from any polar group. The ethylene content of the copolymers should preferably 30 to 80 mol %, preferably 50 to 80 mol %.

The component (B) is used in a proportion of 1 to 20 weight %, preferably 2 to 10 weight % based on the total amount of the compositions. The proportions of the component (B) below 1 weight % and above 20 weight % are unpreferred, since the reduction in the coefficient of traction at low temperatures is increased.

For such ethylene- $\alpha$ -olefin copolymers, commercially available copolymers may be used. By way of example, Lucant HC10, HC20, HC40, HC100, HC150, HC600 and HC2000 (tradename; produced by Mitsui Petrochemical Co., Ltd.) may be used alone or in suitable combinations.

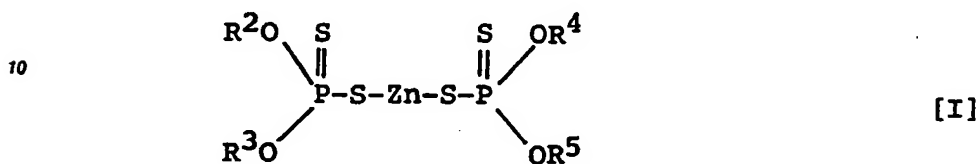
In the present invention, anti-wear agents are further used as the component (C).

The anti-wear agents used may include zinc dithiophosphate; oxymolybdenum or-



ganophosphorodithioate sulfide; phosphoric and phosphorous compound such as, phosphate, phosphite and amine salts thereof; and molybdenum dialkyldithiocarbamate; as well as mixtures of sulfurized fats and oils, and phosphates; mixtures of sulfurized olefin and oils, and phosphites; mixtures of sulfurized olefin and phosphates; mixtures of sulfurized olefin and phosphites; and their amine salts known as sulfur-phosphor-based extreme pressure agent (SP-based extreme pressure agent).

The zinc dithiophosphates are expressed in terms of the following general formula:



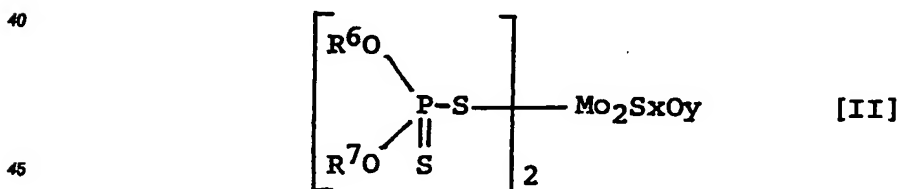
wherein  $\text{R}^2$ ,  $\text{R}^3$ ,  $\text{R}^4$  and  $\text{R}^5$  may be identical or different, and stand for a primary alkyl group having 3 to 30 carbon atoms, a secondary alkyl group having 3 to 30 carbon atoms or an alkyl group-substituted aryl group having 6 to 30 carbon atoms.

Various zinc dithiophosphates expressed in terms of the general formula [I], in which the substituents  $\text{R}^2$  to  $\text{R}^5$  may be identical or different, may be used alone or in combinations. Usually, two or more zinc dithiophosphates, in which all the substituents  $\text{R}^2$  to  $\text{R}^5$  are identical, are mixed together for use. However, such zinc dithiophosphates may be used alone. Zinc dithiophosphates, in which the substituents  $\text{R}^2$  to  $\text{R}^5$  are different, may also be used alone or in a suitable combination with the zinc dithiophosphates in which  $\text{R}^2$  to  $\text{R}^5$  are identical. However, it is noted that, in either case, the zinc dithiophosphate containing a primary alkyl group having 3 to 30 carbon atoms amounts to 1/3, particularly 1/2 (on the weight basis) of all the zinc dithiophosphates.

By using the zinc dithiophosphates in which the zinc dithiophosphate containing a primary alkyl group amounts to at least 1/3 of the total amount of  $\text{R}^2$  to  $\text{R}^5$  in all the zinc dithiophosphates, it is possible to improve further anti-wear property and load carrying capacity and extend fatigue life, thereby enhancing durability.

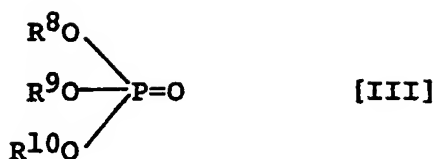
For such zinc dithiophosphates, commercially available ones may be used. By way of example, Lubrizol 1097 ( $\text{R}^2$  to  $\text{R}^5$  are mainly primary octyl groups), Lubrizol 1395 ( $\text{R}^2$  to  $\text{R}^5$  are mainly primary butyl and amyl groups sold by Nippon Lubrizol Co.; OLOA 267 ( $\text{R}^2$  to  $\text{R}^5$  are mainly primary hexyl groups) sold by Kalonite Chemical Co.; Hitec E 682 ( $\text{R}^2$  to  $\text{R}^5$  are mainly primary hexyl groups) sold by Nippon Cooper Co.; and Amoco 198 ( $\text{R}^2$  to  $\text{R}^5$  are mainly primary butyl and amyl groups) sold by Amoco Chemical Co. may be used alone or in suitable combinations. It is then preferred that the proportion of the zinc dithiophosphate, in which the substituents  $\text{R}^2$  to  $\text{R}^5$  are primary alkyl groups, is adjusted to at least 1/3, preferably at least 1/2.

The oxymolybdenum organophosphorodithioate sulfides are expressed in terms of the following formula:



wherein  $\text{R}^6$  and  $\text{R}^7$  may be identical or different, and stand for an alkyl, cycloalkyl, aryl or alkylaryl group having 1 to 30 carbon atoms, and  $x$  and  $y$  are a positive interger satisfying  $x + y = 4$ . The oxymolybdenum organophosphorodithioate sulfides may be prepared by the process disclosed in, e.g., Japanese Patent Publication No. 44-27368. By way of example, reference may be made to oxymolybdenum diisopropylphosphorodithioate sulfide, oxymolybdenum diisobutylphosphorodithioate sulfide, oxymolybdenum di-(2-ethylhexyl)phosphorodithioate sulfide, oxymolybdenum di-(*p*-tertiary butylphenyl)phosphorodithioate sulfide and oxymolybdenum di-(nonylphenyl)phosphorodithioate sulfide.

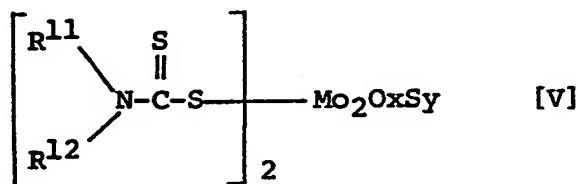
More preferably, the phosphoric and phosphorous compounds are expressed in terms of the following formulae [III] or [IV]:



wherein  $\text{R}^8$ ,  $\text{R}^9$  and  $\text{R}^{10}$  may be identical or different, and stand for a hydrogen atom or an alkyl, aryl or alkyl-substituted aryl group having 4 to 30 carbon atoms.

By way of example, the phosphoric and phosphorous compounds may include phosphates and phosphites such as triphenyl phosphate, tricresyl phosphate, trixylenyl phosphate, tri-(isopropylphenyl)-phosphate, butyl acid phosphate, 2-ethylhexyl acid phosphate, lauryl acid phosphate, oleyl acid phosphate, stearyl acid phosphate, dibutyl hydrogen phosphite, dioctyl hydrogen phosphite, dilauryl hydrogen phosphite, dioleyl hydrogen phosphite and distearyl hydrogen phosphite, and amine salts such as laurylamine, oleylamine, coconut amine and tallow amine salts thereof.

The molybdenum alkyldithiocarbamates are expressed in terms of the following general formula [V]:



wherein  $\text{R}^{11}$  and  $\text{R}^{12}$  may be identical or different, and denote an alkyl group having 1 to 30 carbon atoms, which may or may not contain one oxygen atom therein, or a cycloalkyl, aryl or alkylaryl group having 1 to 30 carbon atoms, and  $x$  and  $y$  are a positive integer satisfying  $x + y = 4$ .

For the molybdenum alkyldithiocarbamates expressed in term of the general formula [V], use may be made of those disclosed in Japanese Patent Publication Nos. 49-6362 and 53-31648, and Japanese Patent Application Laid-open Nos. 56-61397 and 56-62894. By way of example, reference may be made to molybdenum diethyldithiocarbamate sulfide; molybdenum dibutyldithiocarbamate sulfide; molybdenum dimyldithiocarbamate sulfide; molybdenum di(2-ethylhexyl)dithiocarbamate sulfide; molybdenum dilauryldithiocarbamate sulfide; molybdenum di(oleyllinoleyl)dithiocarbamate sulfide; molybdenum dicyclohexyldithiocarbamate sulfide; molybdenum dinonylphenyldithiocarbamate sulfide; molybdenum 2-ethylhexyl sulfide, 2-ethylhexyl-*o*-propoxydithiocarbamate; molybdenum ethylhexyl sulfide, butyl-*o*-propoxydithiocarbamate and molybdenum ethylhexyl sulfide, stearyl-*o*-propoxydithiocarbamate.

According to the present invention, the component(C) as mentioned above should be used in proportions of 0.1 to 10 weight %, preferably 0.5 to 10 weight % based on the total amount of the compositions. A proportion of the component (C) below 0.1 weight % is unpreferred due to an increase in wear losses, whilst a proportion of the component (C) exceeding 10 weight % is undesired due to increased corrosion and deteriorated stability.

The lubricating oil compositions for traction drive according to the present invention comprises the aforesaid components (A) to (C) and, if required, may contain various additives such as anti-foam agents, oiliness agents, friction modifier, corrosion inhibitors and fatigue life improvers, including rust inhibitor, anti-oxidants, pour-point depressants and viscosity index improvers.

Various rust preventing agent may be used. By way of example, reference may be made to calcium sulfonate, barium sulfonate and sodium sulfonate as well as alkyl or alkenyl succinates or their derivatives, alkylamines such as tri-*n*-butylamine, *n*-octylamine, tri-*n*-octylamine and cyclohexylamine, alkylamine or ammonium salts of carboxylic acids such as fatty acids or aromatic carboxylic acids having 6 to 20 carbon atoms and dibasic acids having 2 to 20 carbon atoms, or further condensed products of said carboxylic

acids with amines. Among others, preference is given to calcium sulfonate or barium sulfonate.

As the anti-oxidants, use may be made to phenolic anti-oxidants such as 2,6-di-t-butyl-p-cresol and 4,4'-methylene-bis-(2,6-di-t-butylphenol) and amine base anti-oxidants such as dioctyldiphenylamine.

As the pour-point depressants or viscosity index improvers, reference is made to polymethacrylates having a number-average molecular weight of 10,000 to 100,000 in particular. Besides, olefin copolymers such as ethylene/propylene copolymers and styrene/propylene copolymers may be used to this end.

The lubricating oil compositions of the present invention are effectively used in winter and cold districts, since they have a high coefficient of traction and show a limited change in the coefficient of traction at low temperatures.

## Examples

The present invention will now be explained with reference to the examples. It is understood, however, that the invention is not limited to the examples, unless they depart from the scope defined in the present invention.

### Example of Preparation of (Base Oil)

1000 grams of tetralin (tetrahydronaphthalene) and 300 grams of concentrated sulfuric acid were put in a flask made of glass of 3-liter capacity, the interior of which was then cooled down to 0°C in ice bath. Under agitation, 400 grams of styrene were thereafter slowly added dropwise into the flask over 3 hours. Agitation was continued for further one hour to terminate the reaction. After the interruption of agitation, the reaction product was allowed to stand for the separation of an oily phase. The oily phase was washed with three portions each of 500 cc of an 1 N aqueous solution of sodium hydroxide and 500 cc of a saturated solution of sodium chloride, and was then dried over anhydrous sodium sulfate. After the removal of unreacted tetralin by distillation, distillation was carried out under reduced pressure to obtain 750 grams of a fraction having a boiling point of 135 to 148°C/0.17 mmHg. As a result of analysis, this fraction was found to be a mixture of 1-(1-tetralyl)-1-phenylethane with 1-(2-tetralyl)-1-phenylethane.

500 cc of the fraction was then put in an 1-liter autoclave, into which 50 grams of a 5% ruthenium/carbon catalyst were further added, for 4-hours hydrogenation under a hydrogen pressure of 20 kg/cm<sup>2</sup> at a reaction temperature of 120°C. After cooling, the reaction liquid was filtered for the separation of the catalyst. After subsequent stripping-off of the light material out of the filtrate, the product was analysed. In consequence, it was ascertained that a hydrogenation degree of 99.9% higher was achieved, and the product was a mixture of 1-(1-decalyl)-1-cyclohexylethane with 1-(2-decalyl)-1-cyclohexylethane. The thus obtained mixture was found to have a specific gravity of 0.94 (15/4°C), a kinematic viscosity of 4.9 cSt (100°C), a refraction index  $n_D^{20}$  of 1.5048 and a cis ratio of 88%.

### Example 1 and Comparative Example 1

The components specified in Table 1 were added to the base oil (the component A) obtained in the preparation example in the given proportions to obtain lubricating oil compositions, with which various testings were conducted by the following methods.

## Testing Methods

### 50 Coefficient of Traction

The tests were carried out with a two-cylinder type rolling friction test machine. More specifically, while a cylinder A with a curvature (having a diameter of 52 mm and a radius of curvature of 10 mm) was in contact with a cylinder B with a plane (having a diameter of 52 mm) by 7000 kgf, the cylinder A was rotated at a constant speed (1500 rpm) and the rotational speed of the cylinder B was increased from 1500 rpm. The coefficient of traction was then determined by measuring a traction force occurring between both

cylinders at a slip rate of 5%.

The two cylinders were formed of bearing steel SUJ-2 and buffed on the surfaces to a surface roughness  $R_{max}$  of 0.1 micrometer or less with alumina (0.03 micrometers), and were allowed to be in contact with each other at a Hertz contact pressure of 112 kgf/mm<sup>2</sup>. The results are set out in Table 1.

#### Anti-Wear Test

The four-ball tests according to ASTM D-4172 were conducted under the following conditions to determine wear losses (mm). The results are set out in Table 1.

Conditions: Revolutions per minute - 1,800 rpm.

Load - 30 kgf.

Time - 2 hours.

Oil Temperature - 120°C.

#### Comparative Example 2

Example 1 was repeated, except that 4 weight % of polybutene (having a number-average molecular weight of 2,300) were used in place of the component (B). With the thus prepared lubricating oil composition, various tests were carried out. The results are set out in Table 1 and Figure 1.

Table 1

| No.                      | Composition (weight %) |                   |                |     |        |            | Wear<br>Losses<br>(mm) |
|--------------------------|------------------------|-------------------|----------------|-----|--------|------------|------------------------|
|                          | Component<br>A *1      | Component<br>B *2 | Component C *3 |     | PMA *4 | Polybutene |                        |
|                          |                        |                   | I              | II  |        |            |                        |
| Example 1                | 93.0                   | 4.0               | 0.5            | 0.5 | 2.0    | -          | 0.50                   |
| Comparative<br>Example 1 | 93.0                   | -                 | 0.5            | 0.5 | 6.0    | -          | 0.55                   |
| Comparative<br>Example 2 | 93.0                   | -                 | 0.5            | 0.5 | 2.0    | 4.0        | 0.52                   |

\*1: Base oil obtained in the preparation example.

\*2: Ethylene- $\alpha$ -olefin copolymer having a number-average molecular weight of 2,600.

\*3: I ... Zinc dialkylthiophosphate wherein  $R^2$  to  $R^5$  are primary hexyl groups.

II ... Tricresyl phosphate.

\*4: Polymethacrylate having a number-average molecular weight of 40,000.

#### Claims

1. A lubricating oil composition for traction drive, which consists essentially of:

(A) a base oil containing as the main component a saturated hydrocarbon or hydrocarbons having fused ring and/or nonfused ring,

(B) an ethylene- $\alpha$ -olefin copolymer having a number-average molecular weight of 800 to 8,000, and

(C) an anti-wear agent.

2. A composition as claimed in Claim 1, which contains 1 to 20 weight % of said ethylene- $\alpha$ -olefin copolymer and 0.1 to 10 weight % of said anti-wear agent.

3. A composition as claimed in Claim 1, wherein said saturated hydrocarbon having fused ring includes decalyl group.

4. A composition as claimed in Claim 1, wherein said saturated hydrocarbon having nonfused ring includes cyclohexyl group.

5. A composition as claimed in Claim 1, wherein the ethylene- $\alpha$ -olefin copolymer have a number-average molecular weight of 1,000 to 5,000.

6. A composition as claimed in Claim 1, wherein the ethylene- $\alpha$ -olefin copolymer have a number-average molecular weight of 2,000 to 4,000.

7. A composition as claimed in Claim 1, wherein the ethylene content of the ethylene- $\alpha$ -olefin content is 30 to 80 mol %.

8. A composition as claimed in Claim 1, wherein the anti-wear agent is at least one selected from the group consisting of zinc dithiophosphate; oxymolybdenum organophosphorodithioate sulfide; phosphate; phosphite; amine salt of phosphate; amine salt of phosphite; molybdenum dialkyldithiocarbamate; mixtures of sulfurized fats and oils and phosphates; mixtures of sulfurized fats and oils and phosphites; mixtures of sulfurized olefin and phosphates; mixtures of sulfurized olefin and phosphites; and their amine salts.

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*Fig. 1*